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Origin – cause matrix: a practical approach for identification of waste associated with variation orders

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Abstract

This article has a two-fold aim, namely of reviewing the literature pertaining to waste associated with variation orders and providing a tool for identification of waste zones arising from a variation order. Literature was reviewed about the administration and waste associated with variation orders. Two case studies for the purpose of the study consisted of completed apartment complexes in Cape Town. Variation orders on the respective projects were grouped by number and value in an origin-cause table. The literature review confirmed the likelihood of waste of resources following the occurrence of variation orders. Arguably, the excessive occurrence of variation orders was among factors that contributed to overall higher construction delivery costs and time overruns. By auditing each variation order in terms of the value, origin agent and the cause, it was possible to identify some project aspects that yielded waste of resources. Typically, these were the cost of errors originating from the consultant and the client. The origin-cause matrix could be a tool to provide a breakdown of the probable magnitude of waste associated with variation orders. The study was confined to a limited number of apartment-type construction projects to provide insight into the potential impact of variation orders on project performance. The origin-cause matrix could be a practical tool used to track construction project activities that yield waste. The topic discusses issues that have not been widely covered by previous research studies. The origin-cause matrix was designed as a tool for identification of waste based on a theory of waste formation.

Keywords: Causes, non value-adding, origin agents, variation orders, waste

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Abstrak

Hierdie artikel het 'n tweeledige doel, naamlik 'n literatuuroorsig oor afval wat geassosieer word met wysigingsopdragte, asook die verskaffing van 'n instrument vir die identifisering van afval sones wat onstaan as gevolg van wysigingsopdragte. ‘n Literatuurstudie oor die administrasie van afval as gevolg van wysigingsopdragte is gedoen. Twee gevallestudies oor voltooide woonstelblokke in Kaapstad is vir die doel van die studie gebruik. Wysigingsopdragte vir die onderskeie projekte is groepeer deur nommers en waarde in 'n ontstaan-oorsprong matriks saam te voeg. Die literatuuroorsig bevestig die waarskynlikheid dat afval van hulpbronne onstaan as gevolg van die voorkoms van wysingsopdragte. Argumentsonthalwe, die oortollige voorkoms van wysigingsopdragte was onder faktore wat bygedra het tot 'n oorhoofse konstruksie afleweringskoste asook tydoorskryding. Deur elke wysigingsopdrag te oudit in terme van waarde, oorsprong-agent en die oorsprong daarvan, was dit moontlik om sommige projek-aspekte te identifiseer wat vermorsing van hulpbronne oplewer. Tipies, was hierdie aspekte die koste van foute voortspruitend uit die konsultant en kliënt. Die ontstaan-oorsprong matriks kan 'n instrument wees om 'n afbreking van die moontlike grootte van afval geassosieer met wysigingsopdragte te verskaf. Die studie is beperk tot 'n aantal woonsteltipe konstruksie projekte om insig te verskaf in die potensiële impak van wysigingsopdragte op projek-aanbieding. Die ontstaan-oorsprong matriks kan as 'n praktiese instrument gebruik word om konstruksieprojekte aktiwiteite te volg wat afval oplewer. Die onderwerp bespreek gevalle wat nie wyd gedek is deur vorige navorsing nie. Die ontstaan-oorsprong matriks is ontwerp as 'n instrument vir die identifikasie van afval gebaseer op 'n teorie van afvalvorming.

Sleutelwoorde: Oorsake, nie-waardetoevoeging, oorsprong-agente, wysigingsorders, afval

1. Introduction

A construction contract is a business agreement that is subject to variability. Contractual clauses relating to changes allow parties involved in the contract to freely initiate variation orders within the ambit of the scope of the works without alteration of the original contract. Variation orders involve additions, omissions, alterations and substitutions in terms of quality, quantity and schedule of works. Without contractual clauses, the building contractor would have to agree to erect without any change the building shown on the drawings and represented in the bills of quantities for a contract sum. Ssegawa *et al*. (2002) argued that the spirit in which variation orders are permitted allows the contract to proceed without compiling another contract to cater for the changes. Most contracts make provision for possible variations given the nature of building construction (Finsen, 2005; Wainwright & Wood, 1983). A degree of change should be expected since it is difficult for clients to visualise the end product they procure (Love, 2002). Unforeseen conditions[1]

1 Such as for example adverse ground conditions affecting foundations which become apparent only during excavation.

may arise which require measures that have not been provided for in the contract (Finsen, 2005).

However, the disadvantage of the variation clause is that architects tend not to crystallise their intentions on paper before the contract is signed because they know the variation clause will permit them to finalise their intentions during the term of the contract (Wainwright & Wood, 1983). An unfortunate aspect of the variation clause is that it tends to encourage clients to change their minds and embark on building projects without having properly thought through their project requirements (Finsen, 2005). Traditionally, the clients' *prima* perceived requirements include functionality, durability and optimality. In order to achieve these requirements, clients appoint consultant-teams to advise them on design and optimum use of resources. On the other hand, contractors concern themselves predominantly with construction input costs and their reduction. Little recognition is given to the fact that the clients or their agents may be sources of higher construction costs. Clients and consultants typically forget that issuing numerous variation orders result in higher construction costs. For example, a client who targets a completion date may want works to start on site while the design is still at a sketchy stage. In some cases, the construction works may overlap the design where the contractor will have to wait for the detailed design. As a result, some works are put on hold and others are subject to abortion or demolition. Arguably, the costs for aborted works are wastage of resources and are typically transferred to the client. They contribute to higher construction delivery costs. The construction industry does not grasp that the reduction of the occurrence of variation orders may optimally lower construction delivery costs. Ibbs (1997) concluded that the greater the amount of change the greater the negative impact on both productivity and cost.

2. Categorisation of site instructions

Variation orders are often issued in the form of site or contract instructions. Consequently, variation orders have rightly or wrongly been loosely referred to as site or architect's instructions. It is unclear from the work of various authors and standard forms of contract what instructions should be regarded as variation orders or not. According to Uff (2005) disputes often arise as to whether an instruction actually constitutes a variation order because the contract is silent on a definition of what may constitute a variation. Ssegawa *et al.* (2002) contend that there is no single definition of what a variation is. Not all architect's instructions constitute variation orders such as for example, an instruction to remove defective work (Wainwright & Wood, 1983; FIDIC, 1999). The JBCC[2] (2005) defines a contract instruction as *a written instruction signed and issued by or under the authority of the principal agent to the contractor*. The FIDIC[3] (1999) general conditions clause 3.3 stipulates that the engineer may issue to the contractor instructions and additional or modified drawings which may be necessary for the execution of the works and the remedying of any defects, all in accordance with the contract. But, not all instructions vary the contractual arrangements or the way the works are being undertaken. Consequently, some contract instructions may be considered as variation orders while others may not. It is useful to categorise site instructions on the basis of whether they are variation orders or not. With reference to clause 17 (JBCC, 2005) of the Principal Building Agreement, Finsen (2005) derived five categories of contract instructions including:

- Instruction to vary the design, quality or quantity of works, for example to carry out an additional work. This is a variation order.
- Instruction to resolve discrepancies between contract documents, for example to rectify errors. This is a variation order.
- Instruction to reiterate or enforce contractual provisions, for example to remove from site goods that do not conform to original specifications: this is not a variation order. It becomes a variation order if incidental to instruction in terms of categories 1 and 2.
- Instruction to deal with monetary allowance, for example to indicate how to spend money budgeted under prime cost: this is not a variation order. It becomes a variation order if incidental to instruction in terms of categories 1 and 2.
- Instruction to protect the client's interest, for example to remove from site camp a worker that constitutes a nuisance. This is not a variation order at all.

2 The Joint Building Contracts Committee

3 FIDIC is a French acronym that stands for *Fédération Internationale des Ingénieurs-Conseils* interpreted in English as International Federation of Consulting Engineers

3. Nature of variation orders

The nature of variation orders can be determined by referring to both the reasons for their occurrence and subsequent effects. Arain & Pheng (2005) distinguished two types of variation orders, namely beneficial and detrimental variation orders.

3.1 Beneficial variation orders

A beneficial variation order is one issued to improve the quality standard, reduce cost, schedule, or degree of difficulty in a project (Arain & Pheng, 2005). It is a variation order initiated for value analysis purposes to realise a balance between the cost, functionality and durability aspects of a project to the satisfaction of the client. A beneficial variation order eliminates unnecessary costs from a project; and as a result, it optimises the client's benefits against the resource input by eliminating unnecessary costs. However, it should be noted that regardless of how beneficial a variation order might be, non value-adding costs are likely to accrue as a result. For example, a variation order to solve the discrepancies between contract documents involves the abortion of works that have already been executed. Cost for aborted works should not have been incurred if discrepancies were not found between contract documents.

3.2 Detrimental variation orders

A detrimental variation order is one that negatively impacts the client's value or project performance (Arain & Pheng, 2005). Arguably, a detrimental variation order compromises the client's value system. A client who is experiencing financial problems may require the substitution of quality standard expensive materials to sub-standard cheap materials. For example, on a construction project situated in a salty environment, steel window frames result in steel oxidation if selected *in lieu* of timber or aluminium frames.

4. Waste associated with variation orders

4.1 Concept of waste *vis-à-vis* variability

The paradigm of waste as used in construction has various meanings depending on one's point of view. Very often, waste has been referred to as physical losses of material occurring during the construction process. According to Formoso *et al*. (1999) most studies on waste are based on the conversion model where material losses are considered to be synonymous to waste. Waste is defined as:

> *any inefficiency that results in the use of equipment, materials, labour, or capital in larger quantity than those considered as necessary in the production of the building.* (Formoso *et al.*,1999: p. 325)

However, it should be understood that the contractor recognises allowable waste as the percentage for losses of material allocated to bill rate components by the estimator at tender stage and it varies from one material to another. Unfortunately the existing estimating and contract valuation techniques do not provide a clear breakdown of losses of materials resulting from variation orders. For example, cement that hardens in the stores following a variation order to suspend works is not allocated to the variation order account. Waste of materials resulting from the occurrence of variation orders may, for example, emanate from the following circumstances:

- Compensating waste arising when material ordered for one specific purpose is used for another. For example, facing bricks ordered for external wall erection may be used for internal plastered walls when there is a shortage of common bricks.
- Waste due to the uneconomic use of plant arising when the plant lies idle on site as a result of a variation order. Saukkoriipi & Josephson (2006) estimated the waste for non-productive use of resources at more than 10% of a project's production cost.
- Waste of materials due to incorrect decisions, indecision or inconsistent inspection of works by the project consultant.
- Waste of materials after demolition of a portion of work caused by the variation order to change a trade. For example waste for breaking down a wall to accommodate a new door.
- Waste due to the wrong use of material or waste stemming from materials wrongly specified.

Other authors have defined waste as being not only physical losses of materials. Al-Hakim (2005) defined waste as *anything that adds no value to producing the required services*. The understanding of waste would require an explanation of what value-adding and non value-adding activities are. An activity is value-adding if it is judged to contribute to customer value or satisfy an organisational need (Tsai, 1998). From the perspective of the client, Saukkoriipi (2005) defined non-value adding activities as *those which absorb resources without adding value to the customer*. The value consists of two components, namely production performance and freedom from defects (Koskela, 1992). The production of services requires resources and flow of activities over a certain portion of time.

According to Koskela (1992), the [4]philosophy of production consists of both conversion and flows. Since only conversions add value, the improvement of flow activities should primarily be focused on reducing or eliminating them, whereas conversion activities have to be made more efficient. Therefore, waste reduction is enhanced by avoiding flow variability. In construction terms this refers to avoiding excessive occurrence of variation orders.

4.2 Identification of the origin agent, causes and cost of variation orders

While most construction industry stakeholders are arguably interested in the reduction of overall production costs, they are not always aware of the extent of non-value adding activities on construction projects (Saukkoriipi, 2005). Consequently, there is a lack of knowledge about non value-adding costs associated with variation orders. The realistic quantification of such costs is problematic due to lack of appropriate techniques for their measurement. In common practice, non value-adding costs arising from variation orders that are typically transferred to the client are underestimated. For example, one may be able to calculate the costs of aborted works, but non value-adding costs arising from non-productive time, redesign and overheads are not attributed to such an activity. Very often these costs are unknowingly transferred under the account of contingencies.

It is necessary to uncover non value-adding activities arising from variation orders in order to take proactive measures to reduce them. The reason for variation orders and the magnitude of the associated non value-adding costs should be known. A clearer understanding of variation orders and subsequent waste might be possible if they are categorised by their origin and identification of possible waste zones. Koskela (2000) suggested a framework of the formation for waste and value loss that takes into account the following, namely:

- Waste and value loss;
- Factors causing loss; and
- Root causes.

Every time a task is divided into two subtasks executed by different specialists, non value-adding activities increase, such as, for

4 Philosophy of production refers to an evolving set of methodologies techniques and tools the genesis of which was in the Japanese JIT (Just In Time) and TQC (Total Quality Costs) effort in car manufacturing (Koskela 1992)

example, inspecting, moving and waiting (Koskela, 2000). Similarly, when a variation order is issued, numerous non value-adding activities/costs are likely to arise. These include travelling and communication expenses; idle plant and labour during the waiting time, demolitions, time taken by the designer to understand the required change and redesign; cost and time for litigation in case the misunderstanding arises between the contractor and the client or his/her consultant. These represent a waste of resources and are typically paid for by the client. In addition, a delay of the consultant to issue an appropriate instruction may result in remedial works. Acharya *et al*. (2006) suggested that consultants should aim at getting an understanding of the overall scope and goals of the project, make sure they understand deliverables and offer specific suggestions when they makes sense; and do all relatively quickly without having negative effect on productivity. Furthermore, a lack of judgment and experience of the designer contributes to errors and omissions in the design. However, factors influencing the occurrence of variation orders and their adverse impact on project performance vary from one project to another. Factors include the nature of works, the complexity of the project, procurement method and completeness of design before the works commence on site. Studies revealed a significant reduction in both cost increase and time delay as a result of a complete design before commencement of works on site; hence, the prevention of the likelihood occurrence of variation orders (Koushki *et al.,* 2005).

Variation orders can be avoided if their origin and causes were clearly known (Mohamed, 2001). The identification of the originating root involves identification of the initiator of a variation order. Arain & Pheng (2006) identified four origin agents of variation orders. These included 'client', 'consultant', 'contractor' and 'others'. It is also important to know what could be the reason for a variation order to be issued. A classification of categories/types rework (Love & Sohal, 2003) revealed the following causes or the circumstances under which variation orders could be initiated, namely:

- Design changes which arise from the client/consultant, contractor, occupier and supplier/manufacturer or change initiated for improvement purpose.
- Design errors which are mistakes made in the design.
- Design omissions which arise when an item or component is omitted from the design.

- Construction changes which are initiated to improve constructability or due to site conditions. Change may be made by the client, the consultant or the occupier after some work has been performed on site. Change may be made if the process or product needs` to be altered/rectified or if there is a need to improve quality.
- Construction errors which are the result of erroneous construction methods procedures.
- Construction omission which are those activities that occur due to omission of some activities during the construction.
- Damage caused by accident or inclement weather.

5. Scope of the study

The study is being undertaken in South Africa that is currently experiencing an unprecedented construction boom. While existing infrastructure and buildings are upgraded the backlog in housing and infrastructure delivery, the deficit of skills, the high construction delivery costs and quality standards related problems are current challenges faced by the construction industry. There is growing concern about rising construction delivery costs. Recently, studies have been done in Sweden to investigate the existence of non value-adding (waste) activities in all phases of construction that resultantly give rise to increases in construction costs. The study reported in this article is similar given that it seeks to uncover waste within various activities/ practice in construction projects. The study is confined to variation orders, an area that has not been widely researched.

6. Methodology

In order to identify waste formation zones, the framework suggested under the literature review was considered. Each variation order was audited in terms of three parameters, namely value of the loss, root causes and factors causing loss. This was made possible by designing an origin-causes matrix as illustrated in Table 1. Row A, B, C, *etc.* contain the costs of variation orders as per origin agent and column 1, 2, 3, *etc.* contain the costs of variation orders as per causes. The shaded areas represent the variation orders that are prone to waste. For example, by assuming that column 2 represents construction error and column 5 represents damage, the magnitude of waste is then calculated as follows: (A;2) + (C;2) + (C;5).

Table 1: Illustration of waste zones of variation orders

(Origin - cause)		*Causes*						*Total*
		1	*2*	*3*	*4*	*5*	…	
Origin agents	A		Xx	Xx	Xx			XX
	B	xx		Xx				XX
	C	xx	Xx			Xx		XX
	…	xx			Xx			XX
Total		XX	XX	XX	XX	XX		XX

7. Findings and discussions

7.1 Projects particulars

Primary data was obtained from a reputable cost consultant company in South Africa. A comparative analysis of cost of variation orders was done on two completed apartment complexes; a residential apartment hereby known as project A and shopping apartment hereby known as project B. Records including short descriptions, monetary values, the initiator and reasons for the variation were captured from the variation order files. The occurrence of variation orders were first grouped by number and secondly by value. Variation orders were recorded in a table according to the four origin agents and seven causes of variations identified from the literature. The origin agents included the 'client', the 'consultant', the 'contractor' and 'others'. In this context, 'client' included the development initiator and occupiers/tenants who financed the projects. 'Consultant' included the whole professional team that represented the client. 'Contractor' included the main contractor and his subcontractors. 'Others' included weather conditions, state regulations or any other conditions beyond control of either party to the contract. The seven causes included design change, design error, design omission, construction change, construction error, construction omission and damage. Additional preliminaries costs were added as an eighth column.

The tender sum for project A was R28,315,000 and the original planned works duration was 9 months. The tender sum for project B was R61,617,996 and the original planned works duration was 11 months. In total, 75 and 118 variation orders occurred on respective projects A and B. On project A, there were numerous additional works associated with the continuously revised electrical works. The reinforcement for concrete slabs changed from post-tensioned to conventional rebar. As the contractor could not finish on agreed time, the extension of time of 25 days was granted. Unfortunately, due to a further failure to complete works during the revised completion period, the contractor was charged a penalty of R13,000 per day totalling R923,000 in 71 days above the extended period. Penalty charge amount was 3% of the contract sum and the actual completion period was 12 months with an escalation of 33% above the original time schedule. While there could be other factors that contributed to time escalation, it is argued that numerous changes to electrical works contributed to delays where the contractor might have failed to justify at which extend his productivity and progress were effected. On project B, the contractor was granted an extension of time of 26 days which is a time overrun of 9% over the planned works duration. No penalty was charged to the contractor and the consultant's records did not show in detail the reason behind such an extension.

7.1.1 Variation order occurrence

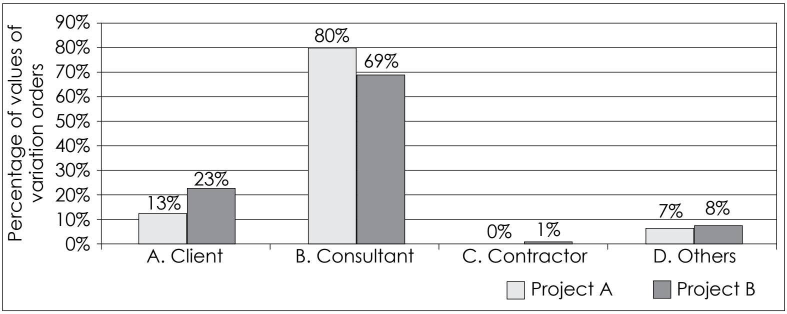

Figure 1: Origin agents of variation orders

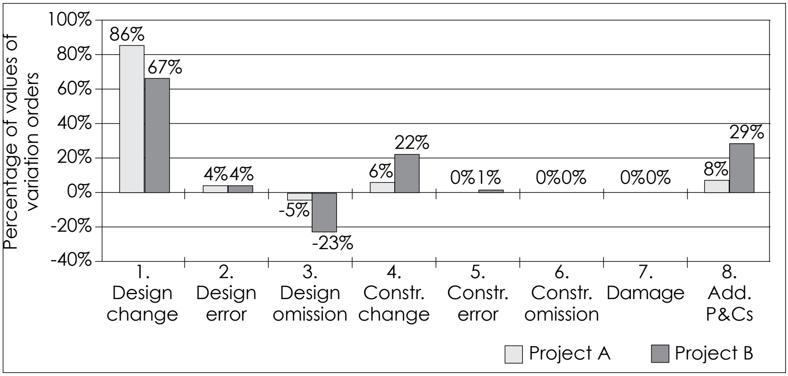

Figure 2: Causes of variation orders

Figure 1 shows the percentage of the value of origin agents of variation orders. For example, on both projects A and B, the consultant was the most predominant origin agent who produced 80% (R1,658,589) and 69% (R1,404,500) of the net total sum of variation orders. Figure 2 shows the percentage of the value of causes of variation orders. On both projects A and B, the design change was the most predominant cause of variation orders that amounted to 86% (R1,784,634) and 67% (R1,363,394) of the net total sum of variation orders. The value of errors and damage is provided for both respective projects are clearly shown. Unfortunately, the chart does not reveal the exact originating agent. Therefore, this will be possible by means of tables that clearly show at the same time parameters including monetary value, origin agent and causes of variation orders.

7.2 Identification of waste zones

Table 2 and 3 record the variation orders that occurred on projects A and B. The origin-cause matrix clearly shows the number and value corresponding at each couple origin-cause. It was possible to identify variation orders that were likely to generate waste. On project A, the cost of the design errors resulting from the consultant (B;2) was 4% (R83,360) of the net total sum. These were costs for remedial works to imported joinery as a result of inefficiency in design co-ordination and repair that was done on electrical cables and conduits damaged. It is argued that costs for demolition of erected works due to design error constitute waste of resources. The construction cost for construction error resulting from the contractor (C;5) was 0.18% (R3,738). Instruction was issued to repair damage done by the contractor (C;7) to neighbouring building during demolition works; but the works were not yet executed and subsequent cost was not provided. On project B, the cost of design errors resulting from the consultant (B;2) was 4% (R82,135) of the net total sum of variation orders and the cost resulting from the construction error of the contractor (C;5) was 1% (R12,395). The combination of the cost of errors originating from the consultant and the contractor amounted to 5% (R94,530) of the net total sum of variation orders. It was revealed that the consultant and the contractor had generated situations that yielded waste. No waste arose from unspecified 'others'. The question is to know who pays for such costs. In most cases, these are transferred to the account of the client and as a consequence, construction delivery cost increased.

Table 2: Origin-Cause matrix of variation orders - Project A

Origin agent		*Causes*								*Total*	*%*
		1	*2*	*3*	*4*	*5*	*6*	*7*	*8*		
A. Client	No	2							1	3	4
	Amount	R98 327							R171 825	R270 152	13
B. Consultant	No	44	3	13	4					64	85
	Amount	R1 596 768	R83 360	-R101 208	R79 669					R1 658 589	80
C. Contractor	No					1		1		2	3
	Amount					R3 738		?		R3 738	0
D. Others	No	3			3					6	8
	Amount	R89 593			R54 582					R144 121	7
Total	No	49	3	13	7	1	0	1	1	75	100
	Amount	R1 784 634	R83 360	-R101 208	R134 251	R3 738	R0	R0	R171 825	R2 076 600	100

Keys: 1. Design change 2. Design error 3. Design omission 4. Construction change 5. Construction error 6. Construction omission 7. Damage 8. Additional Preliminaries

Table 3: Origin-Cause matrix of variation orders - Project B

Origin agent		*Causes*								*Total*	*%*
		1	*2*	*3*	*4*	*5*	*6*	*7*	*8*		
A. Client	No	28		10			1		2	41	35
	Amount	R314 385		-R444 661			R1 640		590 000	R461 364	23
B. Consultant	No	53	4	3	11					71	60
	Amount	R1 049 009	R82 135	-R17 100	R290 456					R1 404 500	69
C. Contractor	No					1				1	1
	Amount					R12 395				R12 395	1
D. Others	No				4		1			5	4
	Amount				R154 660					R154 660	7
Total	No	81	4	13	15	1	2	0	2	118	100
	Amount	R1 363 394	R82 135	-R461 761	R445 116	R12 395	R1 640	R0	R590 000	R2 032 919	100

Keys: 1. Design change 2. Design error 3. Design omission 4. Construction change 5. Construction error 6. Construction omission 7. Damage 8. Additional Preliminaries

8. Conclusions

The review of the literature revealed that variation orders were likely to occur on construction projects since these are permitted under contractual agreements. Variation orders cannot be avoided completely since construction works involve complex operations that cannot be accurately determined in advance. It was argued that whenever a variation order is issued unnecessary costs could likely occur. These constituted waste of resources and as a result they contributed to higher construction delivery costs.

A comparative study was done on two apartment complexes. A total number of 75 and 118 variation orders averaging 8% (R2,076,600) and 4% (R2,032,919) of the contract sum (R28,315,000 and R61,617,996) occurred on respective projects A and B. It is argued that numerous variation orders on both projects contributed to time overruns and had potentially contributed to waste. Both projects A and B incurred delays and time for completion escalated at 33% and 9% over the original completion time. On project A, a contractor was charge a penalty of 3% (R923,000) of the original contract sum. Arguably, the numerous variation orders contributed to delays where the contractor might have failed to properly justify at which extent his productivity and progress were affected. However, there might be other factors beyond the scope of this study that contributed to delays.

By auditing each variation order in terms of the value, origin agent and the cause, it was possible to identify that variation orders were likely to generate waste. On project A, the cost of the error originating from the consultant and the client was 4% (R87,098) of the total net sum (R2,076,600). On project B, the combination of the cost of error originating from the consultant and the contractor was 5% (R94,530) of the net total sum of variation orders (R2,032,919). The origin-cause matrix proved to be an efficient tool that provided a breakdown of uncovering the probable magnitude of waste associated with variation orders.

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